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Flight Operations Risk Assessment System

FORAS

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Introduction

- Flight Operations Risk Assessment System describes a methodology for generating a *risk model*, which produces a relative, quantitative measurement of a specific risk exposure in a flight operation.
- The *risk model* represents the risk factors and their inter-relationships – expressed in software.
- Applicable to many categories of risk: CFIT, Runway incursion, Midair collisions, …*A model for each*
- Method is a structured approach to eliciting and representing domain expert knowledge.
- It is a decision support tool to measure and reduce risk exposure.

Overview

- Motivation
- Project history, Team
- FORAS introduction
- System design
- System user interface
- Model development process
- Implementation requirements
- Conclusion

Motivation – *What we want…*

- Proactive, uniform approach to aviation safety.
- Measure potential for mishap.
- Discuss and communicate “exposure” in uniform terms.
- Answer questions such as:
  - How is our operation doing this month, compared to last?
  - Where is our greatest exposure to mishap? Our least? How do they differ?
- Solution: **uniform, knowledge-based risk model** for each modelled risk category.

Motivation

- All flights have low risk of mishap, thus accidents are a poor measure of safety performance.
- Accidents and incidents:
  - rare enough that a probabilistic approach (an absolute risk) is not likely to be feasible
  - may not accurately reflect risk exposure
  - reflect outcomes, not processes.

- **FORAS captures and quantifies the complex interaction of factors which influence risk.**

- FORAS provides a method for comparing flights, groups of flights, etc., a *relative* risk analysis.

Motivation

- For use at every level of decision making:
  - Can assess overall level of certain risks for any subsection of the flight operation: *flight* to *fleet*.
  - Risk levels can be tracked over time to detect trends.
  - Aids in cost-benefit analysis to compute the “value” of safety investments (in terms of reduced risk).

- Potential risk categories: wherever domain knowledge is available: CFIT, Runway incursions, Turbulence injuries, Midair collisions, Approach&Landing, Loss of Control.

History

- Flight Safety Foundation established Icarus Committee in 1992: safety agenda, safety as a corporate value.
- Initial proposal: Icarus Committee (FSF), 1997.
- FORAS initiated 1998: ERAU, NCAR, NRL.

- Presented at International Air Safety Seminar 1999, SAE Conference on Advances in Aviation Safety 1999, FSF/SAE North American Aviation Safety Conference.
- Principally sponsored by NASA Aviation Safety Program.

- Version 1 delivered 2001: CFIT model,
- Version 2 under development at NRL.
- Committee: Jim Burin, Jack Enders, John McCarthy, Doug Schwartz

Features / Prototype Achievements

- Expert system: built upon the knowledge of experts.
- Summary and real-time analyses, according to data availability.
- Multilevel analysis: “Drill-down” exploration of risk structure; greatest contributors.
- Risk analysis is automatic/continuous, up-to-date, quantitative, consistent, and independent of user bias.
- Potential for expert-system-supplied mitigation strategies.
- Customized and specific to each carrier’s operations: ***Each carrier’s model is a unique adaptation of a generalized model.***

Example uses

- For example,
  - Compare risk assessment of Flight X to baseline or average risk assessment for that route.
  - Compare average assessment of Flight X to that of Flight Y.
  - Assess risk level for Flight X under various environmental conditions or crew rest policies.

Example uses

Strategic

How will risk assessment change when…

…crew rest policies are altered?

…EGPWS is installed in entire fleet?

Why has risk increased for the month of January 2003 compared to January 2002?

Tactical

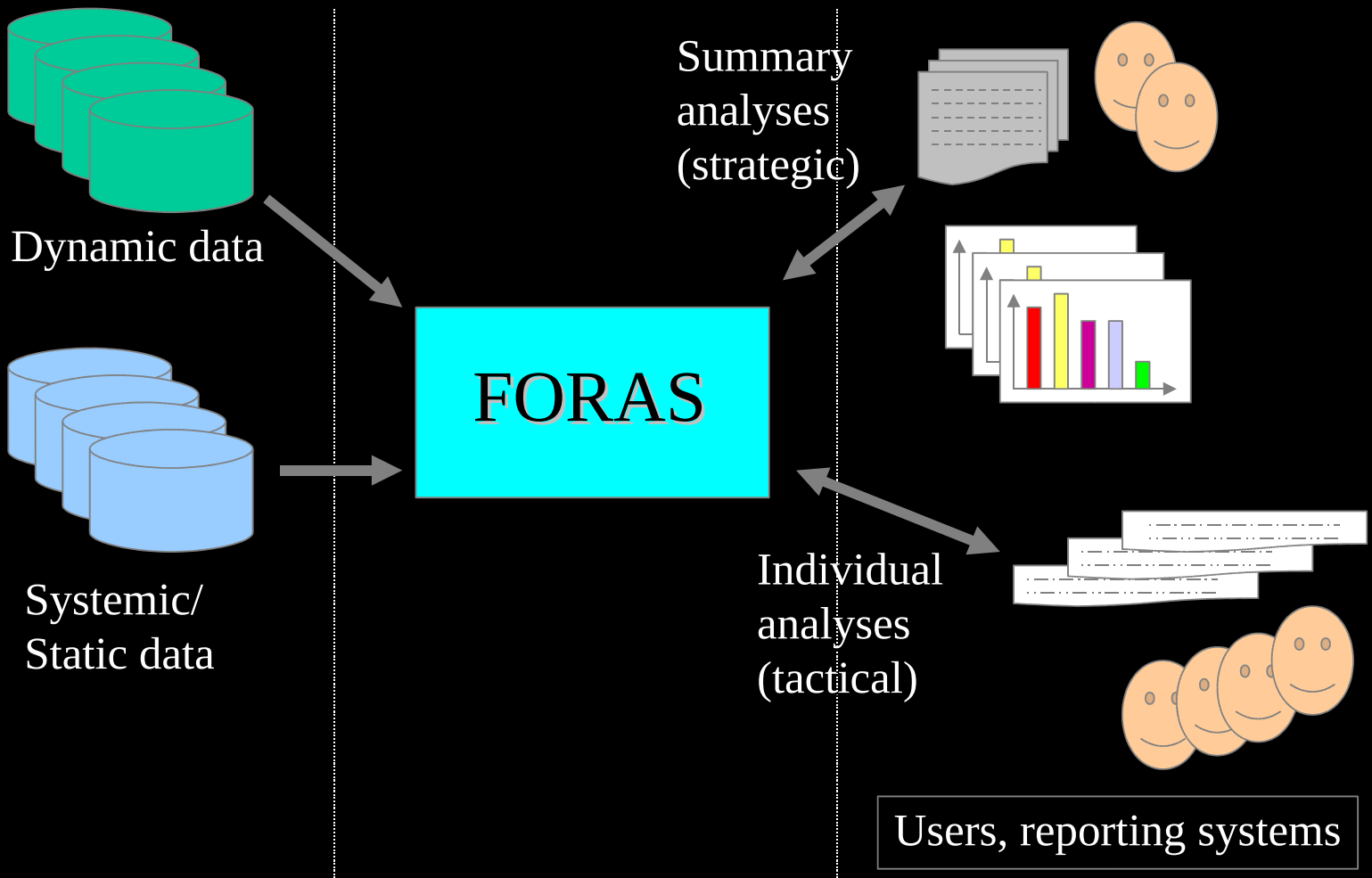
What is the risk assessment for Flight 101 from SFO to JFK on January 1?

Which risk factors are the greatest contributors to the risk assessment?

(…mitigative actions)

Dependent on data availability and system implementation

User System View



Details – *What is FORAS?*

Flight Operations Risk Assessment System

- *Generates a relative risk assessment of a flight operation*:

  – **relative** Not an absolute value: *higher value* ⇒ *higher risk*.

  – **risk** A model for each category of risk; initially CFIT.

  – **assessment** A complex, weighted summarization of the known risk factors contributing to the studied risk, accounting for inter-relationships and based on expert knowledge.

  – **flight operation** Atomic level of analysis is the individual flight. Analyses available at all higher levels.

Definitions: Risk

- Risk: *Potential for incident or accident.*

- Risk attribute (factor): *A factor or condition that influences a specific risk.* For example:

Arrival/Departure airports

Environmental conditions (visibility, day/night, ceiling, …)

Type of equipment installed (GPWS, EGPWS, …)

Navigation Aids

Training procedures

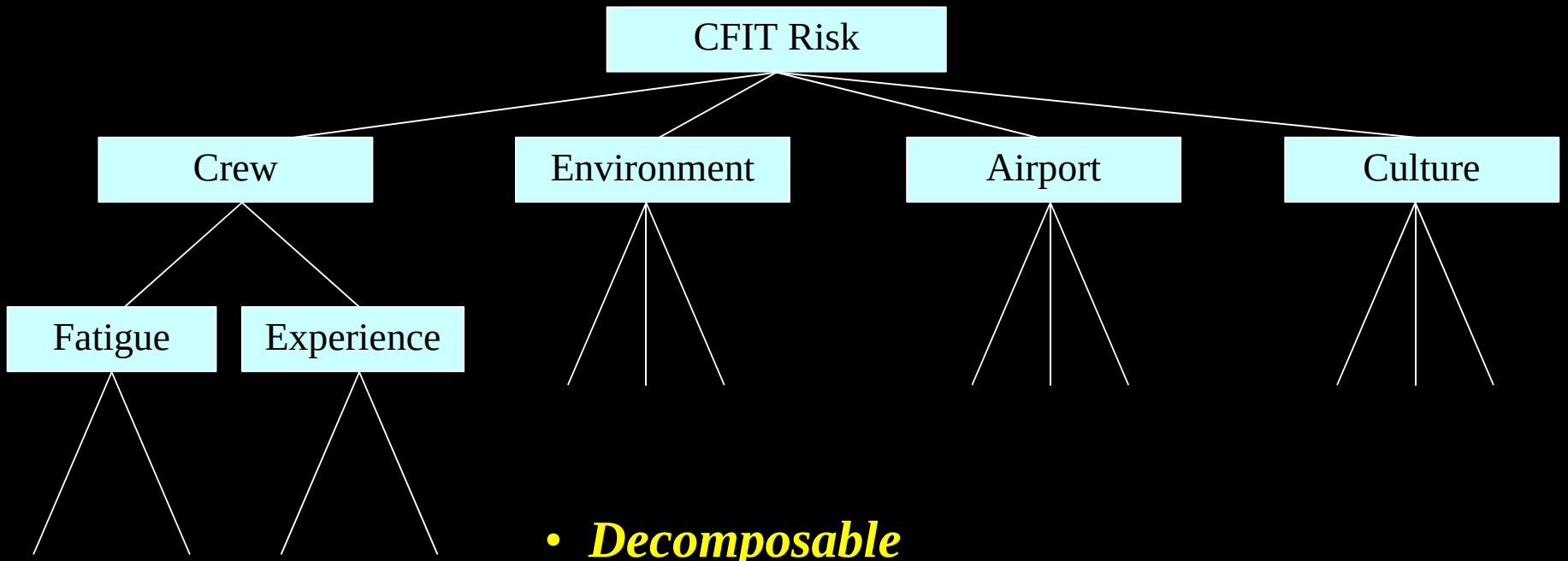
Crew experience

Some more difficult:

- Cockpit distractions
- Crew state-of-mind

Definition: Risk structure

- Risk structure: *Description of a risk in terms of its attributes and their inter-relationships.*



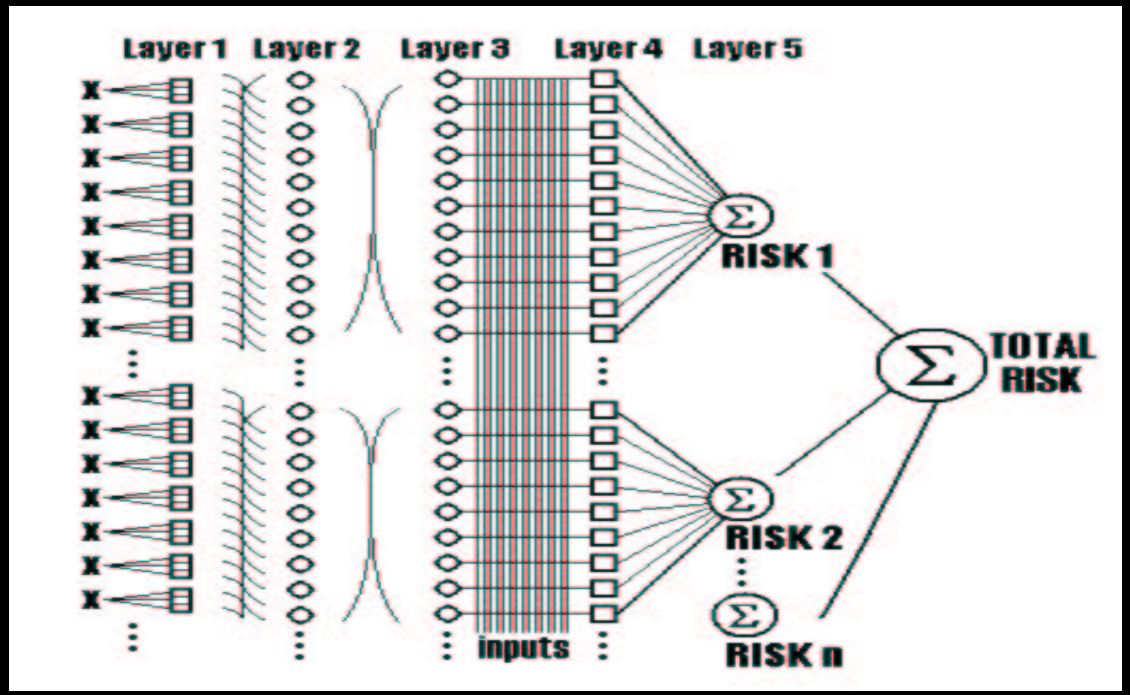
- ***Decomposable***
- ***Hierarchical***
- ***Modular*** → ***Reusable components***

Definition

- Risk model: *A set of mathematical equations (representing the structure) and relating input variables to a risk assessment index.*
  - Expressed as fuzzy rules:

    If captain experience is high and …

    Then crew risk is low
  - Computed by:



Details, continued

- Fuzzy methods for eliciting and representing knowledge in natural language.
- Captures human factors, multiple and cross-dependencies, and non-linear relationships.
- Assessment performed using a mathematical model (fuzzy set based) which synthesizes inputs (e.g., crew, weather, airport).
- Identify those elements that contribute most significantly to the calculated risk, and will be able in some cases to suggest possible interventions.

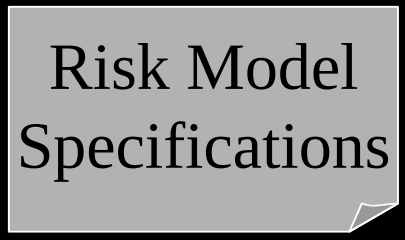
Methodology

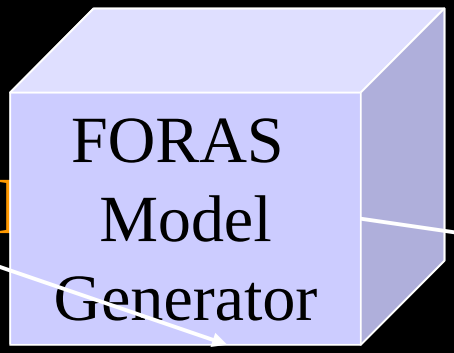
- Create mathematical model of the risk structure based on identified quantifiable risk attributes and available data.
  - –Subject matter experts
  - –Data management experts
  - –Mathematicians/modellers

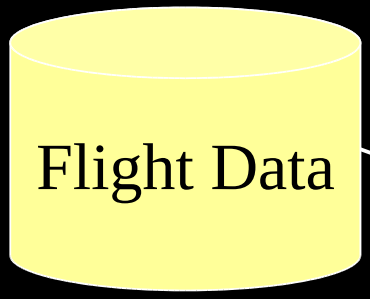
- Inference/Analysis process applies risk model to actual flight data

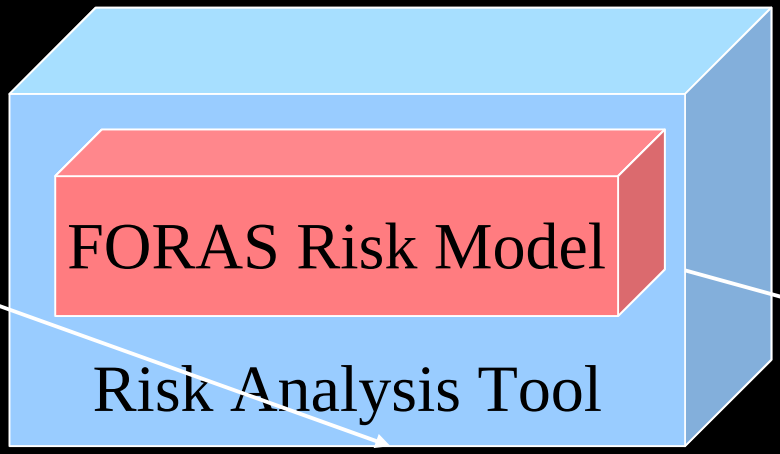
- Describe the result in terms of an index for each risk modeled.

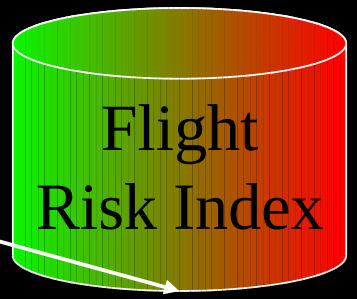
FORAS Project Vision





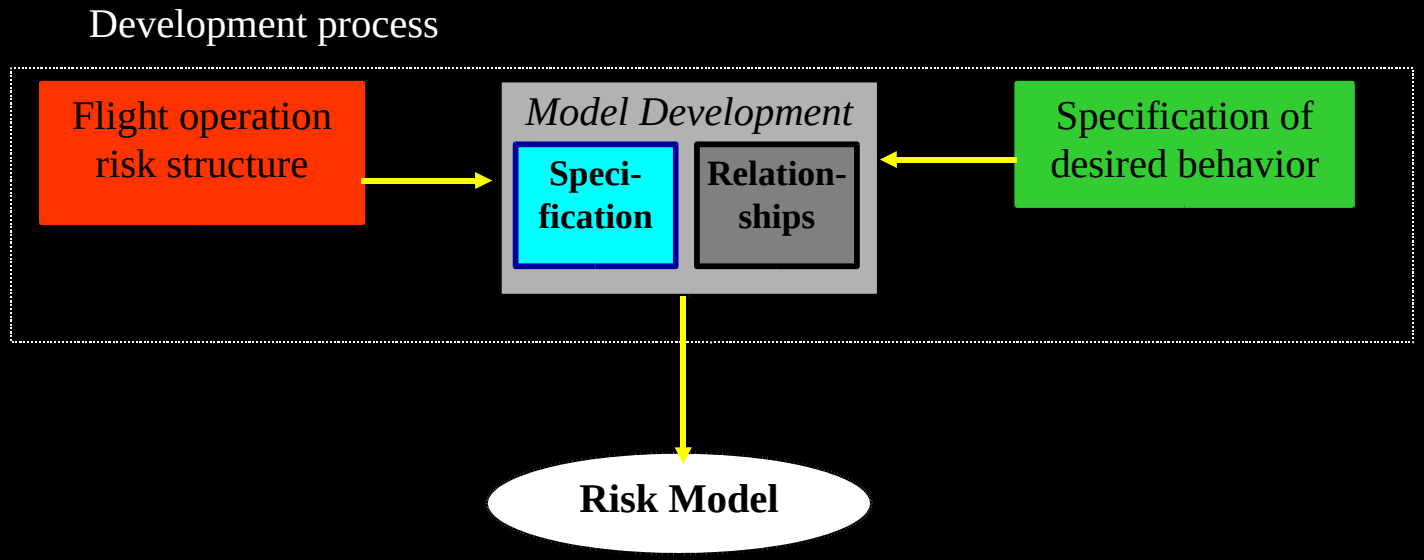






Model Development Process

- **Identification of risk category**
- **Knowledge elicitation:**
  - **Identification of risk factors**
  - **Identification of risk structure**
- **Expression of relationships (fuzzy rules)**
- **Quantification of relationships**



Model Development Process

- Elicitation of risk factors
  - Crew: experience, fatigue
  - Environment: precipitation, ceiling, visibility, time of day, temperature
  - Airport/Aircraft: navigational aids, runway, terrain
  - Safety culture: training programs

- Relationships:

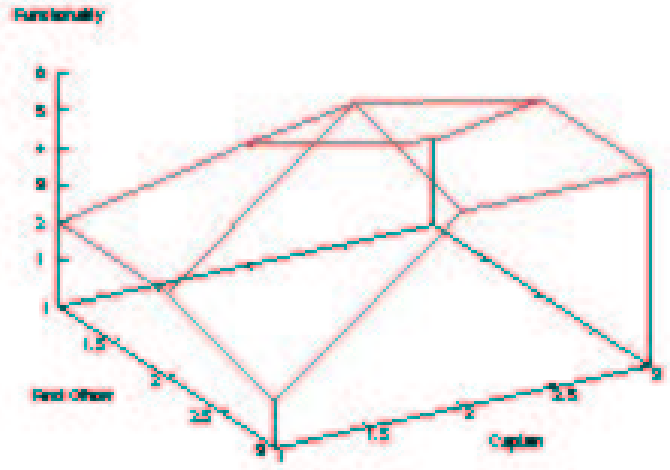
  If *captain-experience* is **high**

  and copilot-experience is **low**

  then *crew-experience* is **medium**.

Simple example!

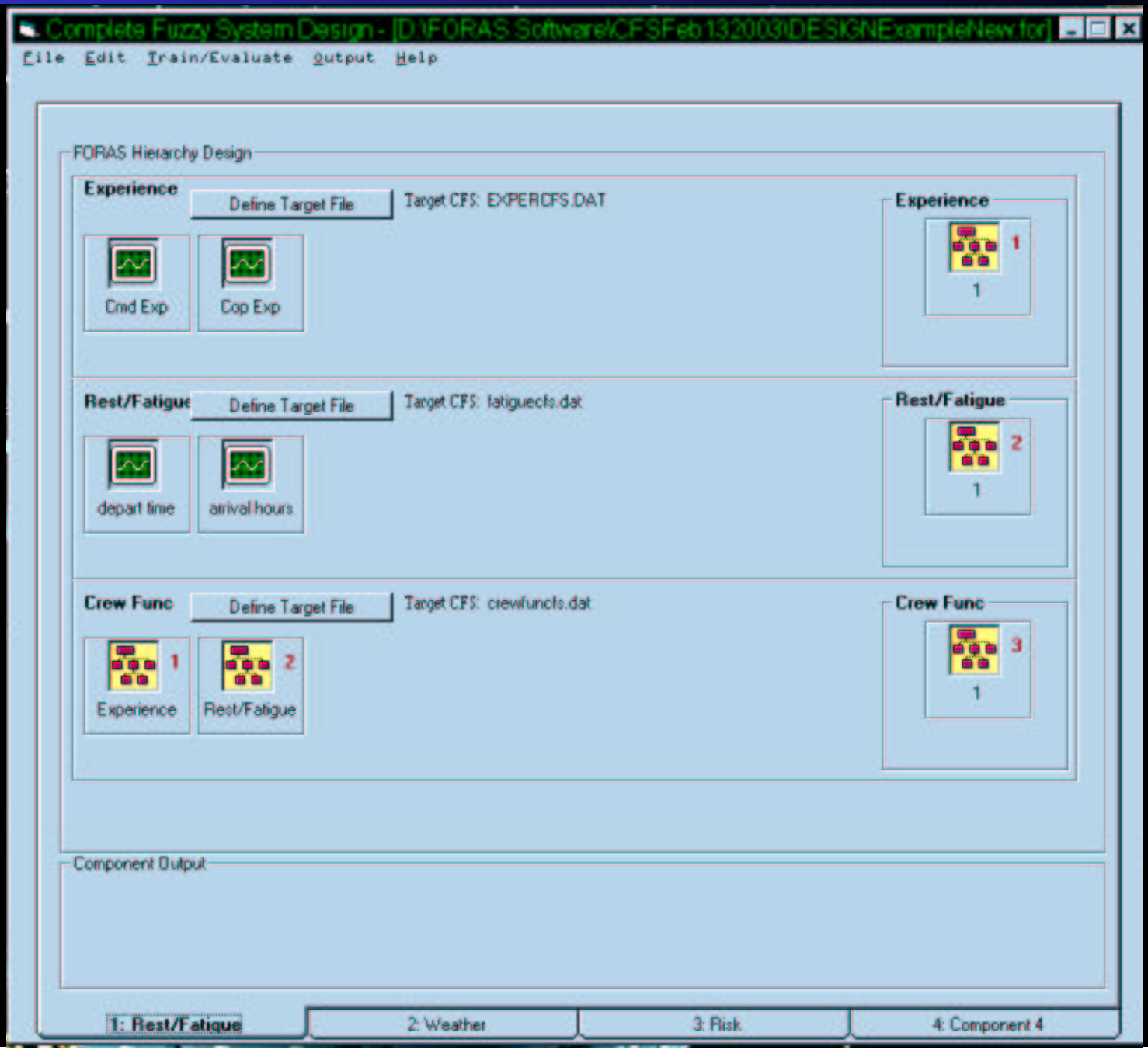
- Includes *non-linear* relationships.



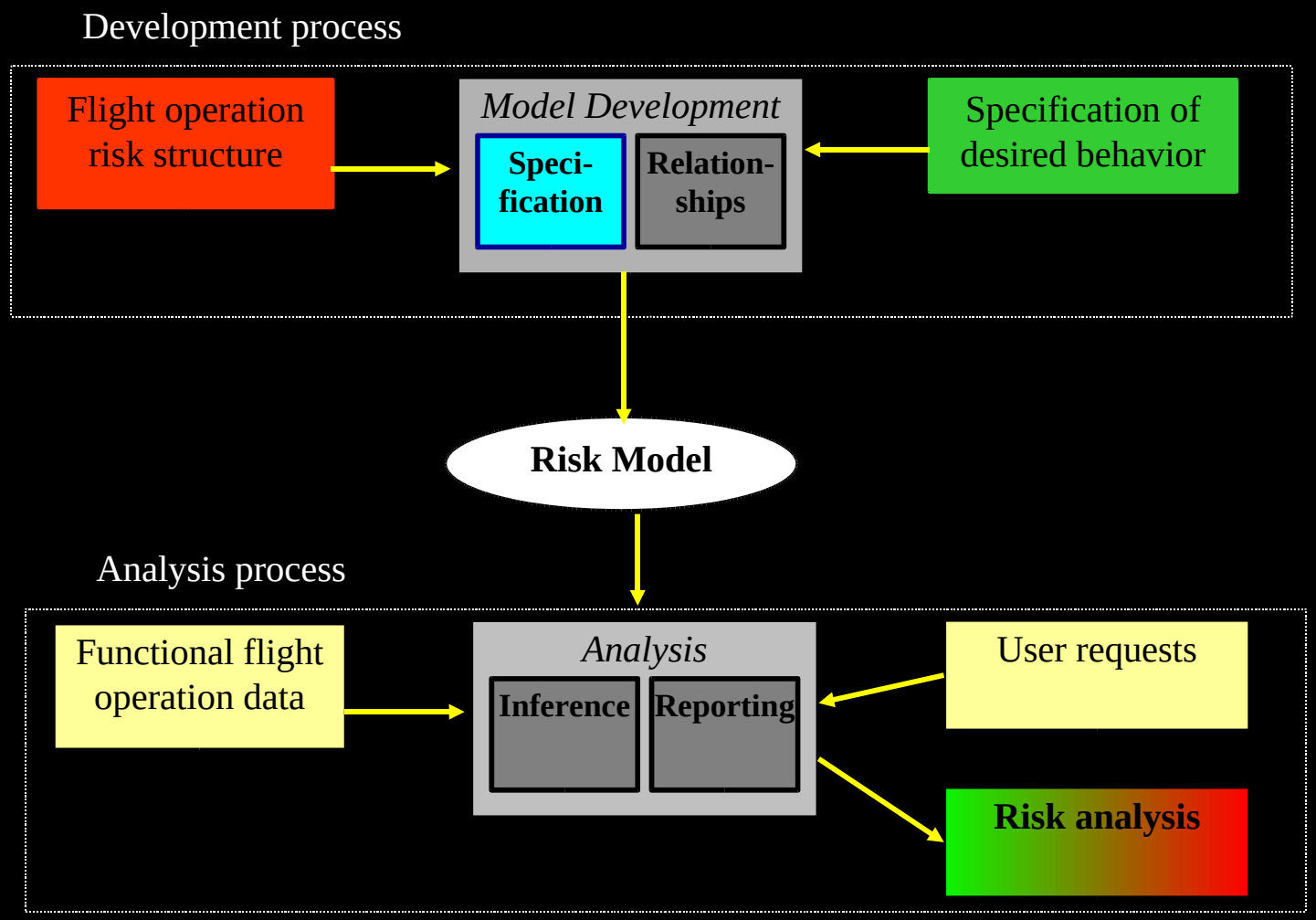
Verification

- A FORAS risk assessment model captures the domain knowledge of a set of experts.
- Value added:
  - Ability to uniformly and consistently consider and evaluate *all* modeled variables,
  - Ability to rapidly evaluate *all* flights
- Verification: Compare FORAS assessment rankings of a small set of flights to rankings by experts.

Interface: *Model Development Tool*



Inference & Analysis Process



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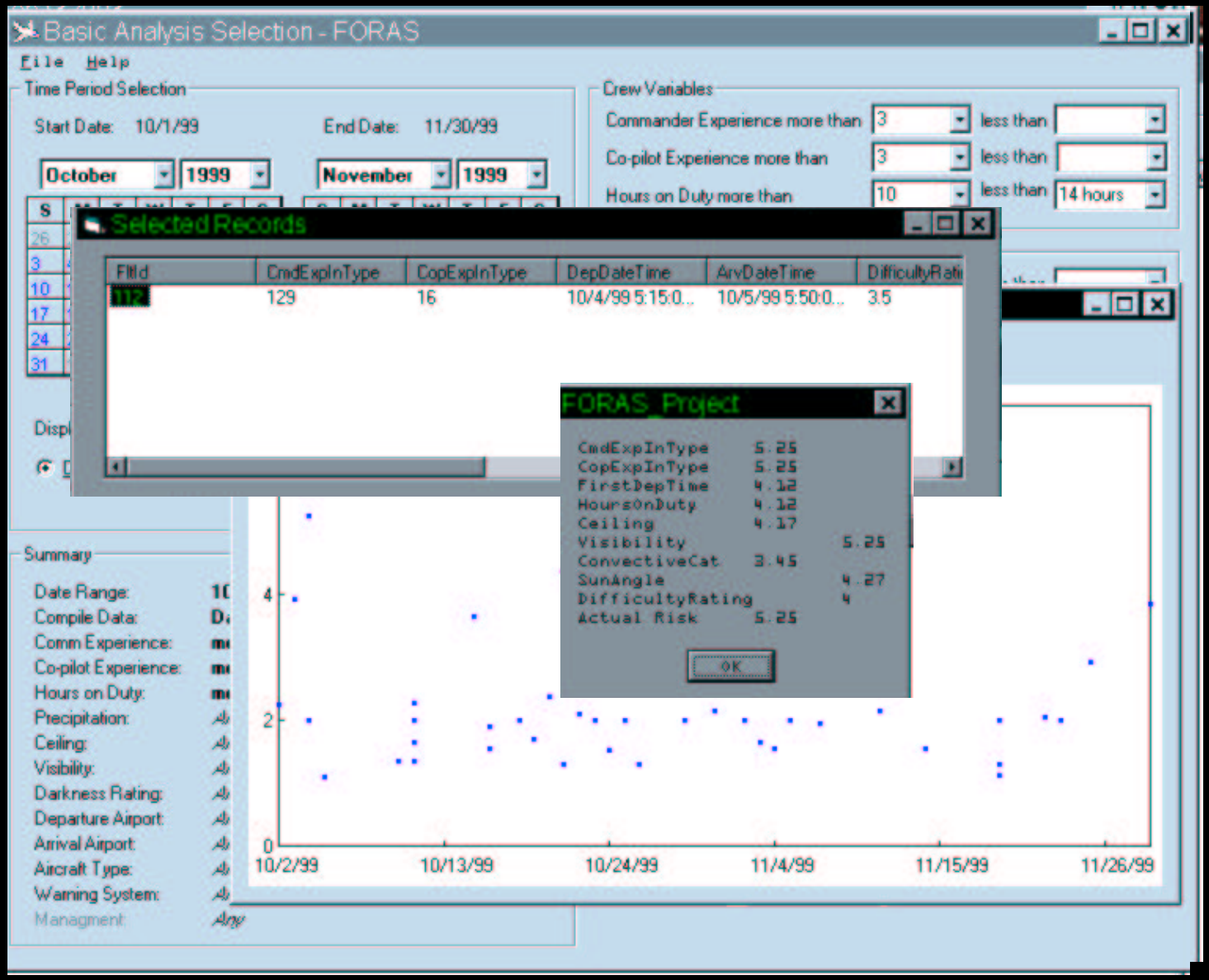
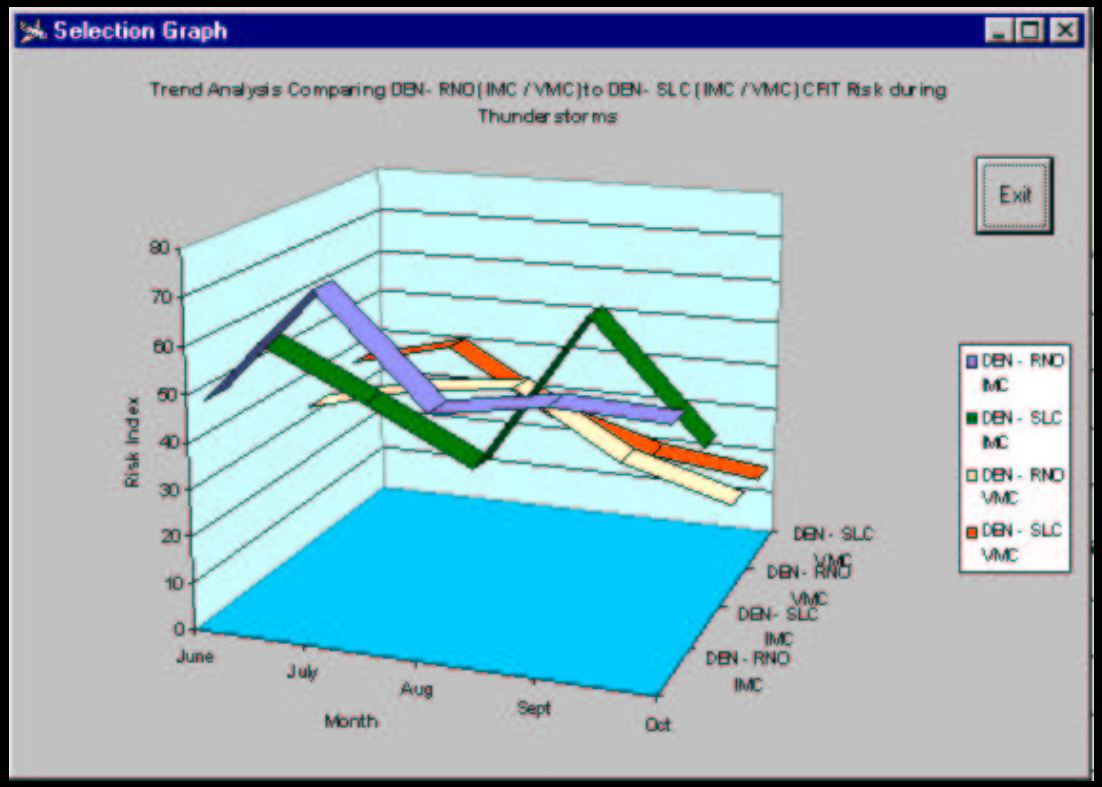
Interface: *Risk Analysis Query Tool*



Interface

Standard spreadsheet analyses:



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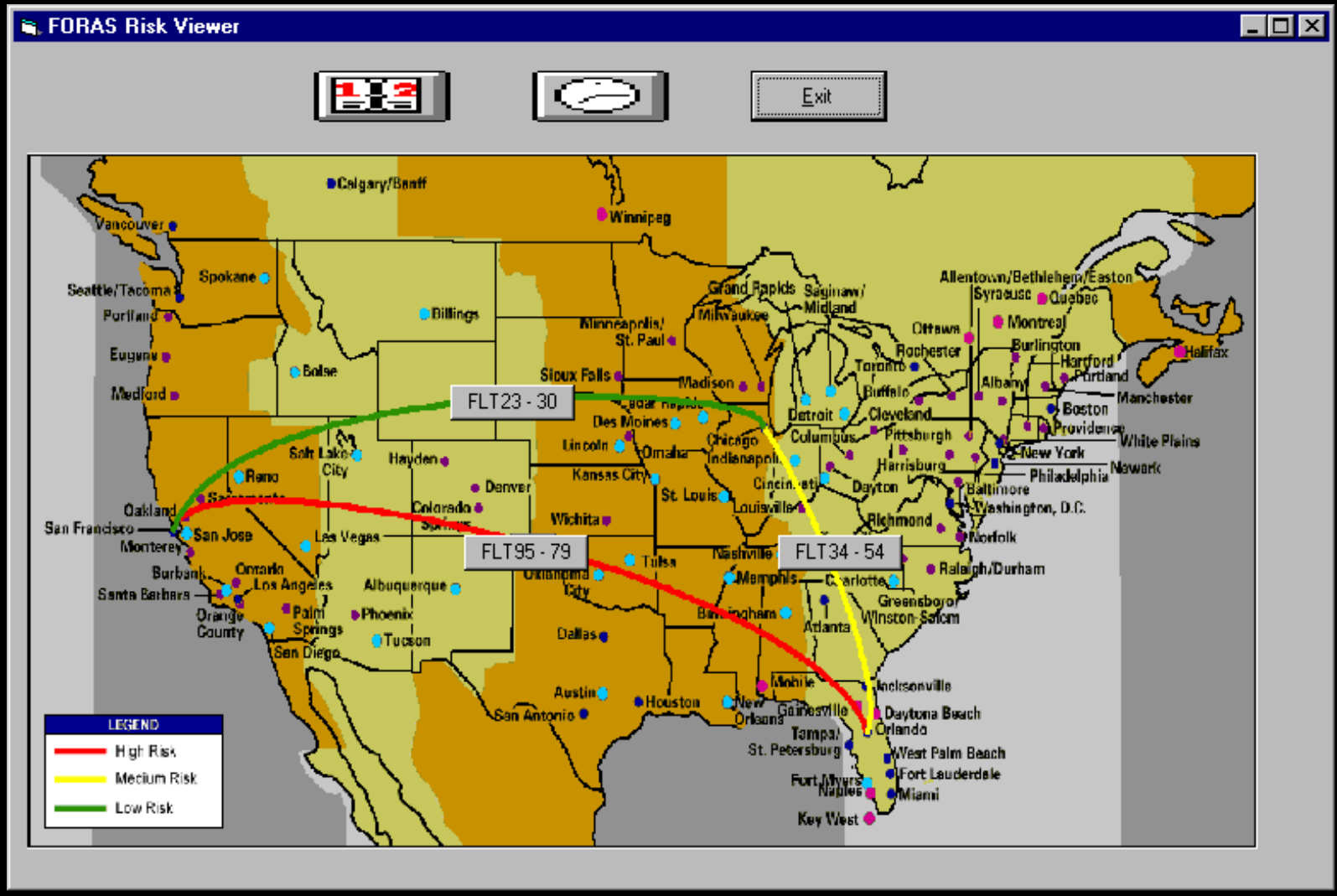
Hypothetical Interface



Implementation Requirements

On-site visits:

1. Introductions, risk selection

3. Knowledge elicitation: *Adaptation of pre-existing components to current situation*

5. Confirmation and validation

7. Delivery and feedback

9. (Follow-on work, improvements)

Personnel Requirements Summary

- Safety Manager
- Domain experts:
  - Pilots
  - Dispatchers
  - Others
- Database experts

Example Data Requirements

- Crew:
  - Static: pilot information (e.g., experience with aircraft type, flight route, and airports; pairings compatibility, turbulence training, etc)
  - dynamic: hours on duty, hours since last shift, etc
- Flight:
  - Origin/destination, data/time, flight path, altitudes, WX forecast availability, visibility conditions, meals, passengers/infants, seatbelt statistics (requests, enforcement, usage), cargo.
- Aircraft (per flight):
  - Aircraft equipment and instrumentation, weight, etc.
- Service provider:
  - ATC workload (current and averages), FAA Facility rating, quality assurance scores, etc.

Varies according to the risk being studied…

Conclusion

- **Encodes expert knowledge about each risk.**
- **Captures human factors, multiple dependencies.**
- **Applicable to a variety of risks.**

1. **Integrate into daily operations as necessary.**
2. **“Real-time” assessment for certain risk categories.**

1. **Aggregate/summary analyses.**
2. **Analysis of risk exposure, planning and policy decisions, etc.**

1. **Communicate risk assessment as a safety evaluation.**
2. **Useful to safety officials to communicate performance to all levels of management.**